

Power-law entropy corrected new holographic scalar field models of dark energy with modified IR-cutoff

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Abstract

In this work, the PLECHDE model with Granda-Oliveros (G-O) IR-cutoff is studied. The evolution of dark energy density, deceleration and EoS parameters are calculated. I demonstrate that under a condition, our universe can accelerate near the phantom barrier at present time. We calculate these parameters also in PLECHDE at Ricci scale, when $\alpha = 2$ and $\beta = 1$, and at last a comparison between Ricci scale, G-O cutoff and non-corrected HDE without matter field with G-O cutoff is done. The correspondence between this model and some scalar field of dark energy models is established. By this method, the evolutionary treatment of kinetic energy and potential for quintessence, tachyon, K-essence and dilaton fields, are obtained. I show that the results has a good compatibility with previous work in the limiting case of flat, dark dominated and non corrected holographic dark energy.

Keywords: Entanglement of quantum field; Ricci scale; Power law entropy correction; Holographic DE

I. INTRODUCTION

Now a days, dark energy is one of the well known scenarios in modern cosmology. Recent astrophysical observations such as data from distant SNIa, LSS and CMBR, reveal that our universe treats under an accelerated expansion [1]. This expansion may be driven by a mysterious energy component with negative pressure, so called, dark energy (DE), which fills $\sim 3/4$ of total energy contents of our universe with an effective equation of state (EoS) parameter $-1.48 < w_{eff} < -0.72$ [2]. Despite of many efforts in this subject, the nature of DE is the most mysterious problem in cosmology. The cosmological constant is the simplest candidate for DE, called Λ CDM model. It has a constant energy density and pressure with a constant equation of state. The Λ CDM model suffers two known difficulty as follows: cosmic coincidence and fine tuning problems. The cosmic coincidence problem requires that our universe behaves in such a form that the ratio of dark matter to dark energy densities must be a constant of order unity or varies more slowly than the scale factor and finally reaches to a constant of order unity [3–5]. In order to avoid these difficulties, the cosmologists proposed dynamical models of DE. The holographic dark energy (HDE) proposal, based on holographic principle, is one of the most attractive candidates of dynamical DE, which has been widely extended in many literatures [6]. According to the holographic principle, the number of degrees of freedom in a bounded system should be finite and has a relationship with the area of its boundary [7]. The holographic principle is a fundamental principle in quantum gravity. In quantum field theory, a short distance (UV) cutoff, Λ , is related to the long distance (infrared) cutoff, L , due to the limit set by forming a black hole. In the other words, the zero-point energy of a system with size L should not exceed the mass of a black hole with the same size. This fact directs us to $L^3 \Lambda^3 \leq (M_P L)^{3/2}$ [8, 9], where M_P is reduced Plank mass. From this inequality, one can obtain a limit for energy density corresponding to the zero point energy and cutoff Λ as $\rho_\Lambda \leq M_P^2 L^{-2}$ or $\rho_\Lambda = 3n^2 M_P^2 L^{-2}$, where $\rho_\Lambda \sim \Lambda^4$. Here n is a numerical constant and coefficient 3 is given for convenience [10, 11]. The IR-cutoff L plays an essential role in this model. If L is chosen as particle horizon, the HDE can not drive an acceleration expansion [12], while for future event horizon, Hubble scale “ $L = H^{-1}$ ”, and apparent horizon as an IR-cutoff (AH-IR-cutoff), an accelerated expansion can be driven by HDE model and the coincidence problem can also be solved [3, 13–15]. More recently, a model of interacting HDE at Ricci’s scale, in which $L = (\dot{H} + 2H^2)^{-1/2}$

has been proposed. They performed an extending discussion on the cosmic coincidence problem, age problem and obtained some observational constraints on their's model [16]. Granda and Oliveros proposed a new IR-cutoff for holographic DE (named new holographic DE) which include a term proportional to \dot{H} [17, 18]. Despite of the holographic dark energy based on the event horizon, this model depends on local quantities, avoiding in this way the causality problem. They showed that power law expansion can appear as the solution of friedmann equations. Their model can generate scalar field potentials which give rise to scaling solutions in a FRW cosmological background. Also the author with collaborators, studied the Cosmological evolution and statefinder diagnostic for new holographic DE model in non flat universe [19].

Although it has not been proposed any well quantum field theory prescription of DE scenario, it is believed that the thermodynamical description of an accelerating universe may reveal the nature of it. In the HDE model, the area law of entropy, “ $S_{\text{BH}} = A/(4G)$ ”, is satisfied on the horizon [20]. Here $A \sim L^2$ is the area of horizon. Therefore this model is strongly connected to entropy of spacetime in Einstein gravity. Any correction to entropy, affects directly on the energy density of HDE.

The entropy-corrected dark energy models based on quantum field theory and gravitation have been widely extended by many authors in the recent years [21, 22]. The motivation of these corrections has been based on black hole physics, where some gravitational fluctuations and field anomalies can affect the entropy-area law of black holes. The logarithmic corrections and power-law corrections are two procedure in dealing with this fluctuations. We know that the gravitation is the base of cosmology. The gravitational entropy plays a crucial role in this connection.

The “power-law corrected entropy (PLEC)” is appeared in dealing with the entanglement of quantum fields in and out of the horizon [23]. The entropy of PLEC is given by [24]

$$S = \frac{A}{4G}[1 - K_{\gamma}A^{1-\gamma/2}], \quad (1)$$

where α is a dimensionless positive constant and

$$K_{\gamma} = \frac{\gamma}{4-\gamma}(4\pi r_c^2)^{\gamma/2-1}. \quad (2)$$

Here r_c is the crossover scale. Further details are referred by [23–25]. It is worthwhile to mention that in the most acceptable range of $4 > \gamma > 2$ [23, 24], the correction term

(i.e. the second term of (1)), is effective only at small A 's and it falls off rapidly in large values of A . Therefore, by large horizon area, the entropy-area law is recovered. However the thermodynamical considerations predict that the case $\gamma \leq 2$ may be acceptable, but it should be removed for cosmic coincidence consideration [5]. Due to entropy corrections to the Bekenstein-Hawking entropy (S_{BH}), the Friedmann equation should be modified [21]. In comparison with ordinary Friedman equation, the energy density of PLECHDE, has been given by [26]

$$\rho_D = 3n^2 M_p^2 L^{-2} - \delta M_p^2 L^{-\gamma}, \quad (3)$$

where δ and γ are the parameters of PLECHDE model. The ordinary HDE is recovered for $\delta = 0$ or $\gamma = 2$.

Recently, the HDE and agegraphic/newagegraphic dark energy (ADE/NADE) models have been extended regarding the entropy corrections (ECHDE, PLECHDE, PLECNADE) and a reconstruction with $F(R)$ gravity has been performed [27].

The outline of my paper is as follows: In Sec. II, the PLECHDE model with G-O IR-cutoff is studied and the evolution of dark energy, deceleration parameter and EoS parameter are calculated. In Sec. III, the correspondence between this model and some scalar field of dark energy models is established. The paper is finished with some concluding remarks.

II. GENERAL FORMALISM OF PLECNHDE MODEL

The energy density of PLECHDE model with G-O IR-cutoff in Planck mass unit, in which $(8\pi G)^{-1/2} = M_P = 1$, can be given by

$$\rho_D = 3(\alpha H^2 + \beta \dot{H}) - \delta(\alpha H^2 + \beta \dot{H})^{\frac{\gamma}{2}}, \quad (4)$$

where we are using G-O scale as: $L_{GO} = (\alpha H^2 + \beta \dot{H})^{-1/2}$ [17], including two constants, α and β , with the Hubble parameter H and its time derivative \dot{H} . Here also δ and γ are two parameters of the PLECHDE model. The line element metric of a non-flat FRW universe with spacial curvature parameter k is

$$ds^2 = dt^2 - a^2(t) \left(\frac{dr^2}{1 - kr^2} + r^2 d\theta^2 + r^2 \sin(\theta)^2 d\phi^2 \right), \quad (5)$$

where $a(t)$ is the scale factor, and $k = -1, 0, 1$ corresponds to the open, flat, and closed universe, respectively. The Friedmann equation for a non-flat universe dominated with two

dark components, energy and matter, is written by

$$H^2 + \frac{k}{a^2} = \frac{1}{3}(\rho_D + \rho_m). \quad (6)$$

By introducing, as usual, the fractional energy densities as

$$\Omega_m = \frac{\rho_m}{\rho_{cr}}, \quad \Omega_K = \frac{K}{H^2 a^2}, \quad \Omega_D = \frac{\rho_D}{\rho_{cr}} = L_{GO}^{-2} H^{-2} \left(1 - \frac{\delta}{3} L_{GO}^{-\gamma+2}\right), \quad (7)$$

where $\rho_{cr} = 3H^2$ is the critical energy density, the Friedmann equation will be rewritten as

$$\Omega_D + \Omega_m = 1 + \Omega_K. \quad (8)$$

Once again to preserve the Bianchi identity or local energy-momentum conservation law, $\nabla_\mu T^{\mu\nu} = 0$, the total energy density $\rho_{tot} = \rho_D + \rho_m$ is satisfied in the following equation

$$\dot{\rho}_{tot} + 3H(1+w)\rho_{tot} = 0 \quad (9)$$

where $w = p_{tot}/\rho_{tot}$ is the total equation of state (EoS) parameter. In the absence of any interaction between dark energy and pressureless cold dark matter (CDM) with subscript 'm', two energy densities ρ_D and ρ_m are conserved separately and the conservation equations are written as

$$\dot{\rho}_D + 3H(1+w_D)\rho_D = 0, \quad (10)$$

$$\dot{\rho}_m + 3H\rho_m = 0. \quad (11)$$

Using Eq. (4) and the time derivative of G-O scale: $\dot{L}_{GO} = -H^3 L_{GO}^3 (\alpha \dot{H}/H^2 + \beta \ddot{H}/2H^3)$, the time derivative of ρ_D is

$$\dot{\rho}_D = 6H^3 \left(\alpha \frac{\dot{H}}{H^2} + \beta \frac{\ddot{H}}{2H^3} \right) \left(1 - \frac{\gamma\delta}{6} L_{GO}^{-\gamma+2} \right). \quad (12)$$

Taking time differential of Eq. (6) and using Eqs. (12, 7, 8, 11), we find

$$\alpha \frac{\dot{H}}{H^2} + \beta \frac{\ddot{H}}{2H^3} = \frac{\left[1 + \frac{\dot{H}}{H^2} - \left(\frac{u}{2} - 1\right) \Omega_D \right]}{1 - \frac{\gamma\delta}{6} L_{GO}^{-\gamma+2}}. \quad (13)$$

Also from G-O scale and Ω_D in (7), we have, $\dot{H}/H^2 = \left(\frac{\Omega_D}{1 - \frac{\delta}{3} L_{GO}^{-\gamma+2}} - \alpha \right) / \beta$, therefore the Eq. (12) yields

$$\dot{\rho}_D = 3H^3 \left[\frac{2}{\beta} \left(\frac{\Omega_D}{1 - \frac{\delta}{3} L_{GO}^{-\gamma+2}} - \alpha + \beta \right) + (u-2)\Omega_D \right], \quad (14)$$

where $u = \rho_m/\rho_D = \Omega_m/\Omega_D$ is the ratio of energy densities.

Differentiating of Ω_D with respect to cosmic time and using $\dot{\Omega}_D = H\Omega'_D$, gives

$$\Omega'_D = \left[\frac{2}{\beta} \left(\frac{\Omega_D}{1 - \frac{\delta}{3} L_{GO}^{-\gamma+2}} - \alpha + \beta \right) \right] + u\Omega_D, \quad (15)$$

where the dot and prime denote the derivative with respect to the cosmic time and the derivative with respect to $x = \ln a$, respectively. At last, using Eqs. (7, 10, 14), the EOS parameter and deceleration parameter $q = -1 - \dot{H}/H^2$ as a function of L_{GO} , Ω_D and H , can be obtained as

$$w_D = -\frac{2}{3\beta\Omega_D} \left(\frac{\Omega_D}{1 - \frac{\delta}{3} L_{GO}^{2-\gamma}} + \beta - \alpha \right) - \frac{1}{3}(1 + u), \quad (16)$$

$$q = \frac{1}{\beta} \left(\alpha - \beta - \frac{\Omega_D}{1 - \frac{\delta}{3} L_{GO}^{2-\gamma}} \right), \quad (17)$$

where from (7) and (17), we have

$$\frac{\Omega_D}{1 - \frac{\delta}{3} L_{GO}^{2-\gamma}} = L_{GO}^{-2} H_{GO}^{-2} = \alpha - \beta - \beta q. \quad (18)$$

At Ricci scale where $\alpha = 2$ and $\beta = 1$, these parameters yield

$$w_D^R = -\frac{2}{3\Omega_D} \left(\frac{\Omega_D}{1 - \frac{\delta}{3} L_R^{2-\gamma}} + -1 \right) - \frac{1}{3}(1 + u), \quad (19)$$

$$q^R = 1 - \frac{\Omega_D}{1 - \frac{\delta}{3} L_R^{2-\gamma}}, \quad (20)$$

find Also from Eqs. (10, 11), the evolution of u , is governed by

$$\dot{u} = 3Huw_D. \quad (21)$$

At present time ($\Omega_D \approx 2/3$, $u \approx 0.4$) from (16, 17), the EoS parameter become: $w_D \approx q - 0.47$. The universe exist in accelerating phase ($q < 0$) if $w_D < -0.47$ and the phantom divide, $w_D \leq -1$, may be crossed provided that $q \lesssim -0.53$. This condition give us: $\dot{H}_0/H_0^2 \gtrsim -0.47$ and from Eq. (17), we have $L_{GO-0}^{-2} H_0^{-2} \gtrsim \alpha - 0.47\beta$. Also the transition between deceleration ($q > 0$) to acceleration ($q < 0$) phases took place at $L_{GO-acc}^{-2} H_{acc}^{-2} = \alpha - \beta$. However from recent analysis of SNe+CMB data with the λ CDM model, our universe began to accelerate at redshift around $z \sim 0.52 - 0.73$ [1].

Recently, Wang and Xu [28], by using some observational data, have constrained the new HDE model in non flat universe. The best fit values of the new HDE model parameters

TABLE I: Comparison of $L^{-2}H^{-2}$, q , and w in three models of DE

DE models	$L_{acc}^{-2}H_{acc}^{-2}$	$L_0^{-2}H_0^{-2}$	q_0	w_0
NHDE	1	1	-1.23	-1.56
PLECHDE-R	1	1.53	-0.53	~ -1
PLECHDE-GO	0.38	0.65	-0.54	~ -1

(α, β) with their confidence level are obtained as: $\alpha = 0.8824_{-0.1163}^{+0.2180}$ (1σ) $_{-0.1378}^{+0.2213}$ (2σ), $\beta = 0.5016_{-0.0871}^{+0.0973}$ (1σ) $_{-0.1102}^{+0.1247}$ (2σ). Therefore the PLECNHDE crossing the phantom barrier at present time ($z = 0$), if: $L_{GO-0}^{-2}H_0^{-2} \gtrsim 0.65$. At deceleration acceleration phase transition, we find: $L_{GO-acc}^{-2}H_{acc}^{-2} \sim 0.38$. It is worthwhile to mention that at Ricci scale, at present time, the dark energy behaves as phantom if $L_{GO-0}^{-2}H_0^{-2} > 1.53$ and our universe started the acceleration expansion from $L_{GO-acc}^{-2}H_{acc}^{-2} = 1$.

In limiting case for ordinary new holographic ($\delta = 0$) in flat universe without any matter field, ($u = 0$, $\Omega_D = L_{GO}^{-2}H^{-2} = 1$), we find

$$H = \frac{\beta}{\alpha - 1} \frac{1}{t}, \quad (22)$$

and Eqs. (16, 17) reach to

$$w_D^O = \frac{2}{3} \frac{\alpha - 1}{\beta} - 1, \quad (23)$$

$$q^O = \frac{\alpha - 1}{\beta} - 1. \quad (24)$$

where have a good compatibility with [17].

In table (I), we compare three cases: (I). non corrected HDE with G-O cutoff, $u = 0$ and $\Omega_D = 1$, (NHDE), (II). PLECHDE with G-O cutoff (PLECHDE-GO) and (III). PLECHDE in Ricci scale (PLECHDE-R).

In this table we see that our universe may be behave around phantom barrier at present time if we use PLECHDE as dark energy model with G-O cutoff or Ricci scale. In the case NHDE, the evolution of our universe can express only at phantom phase, far from the phantom barrier. Recent observational data suggest that w does not depart from -1 at sufficiently low redshift or present time [29].

III. PLECNHDE SCALAR FIELD MODELS

In this section the correspondence between PLECNHDE and famous scalar field models of DE such as quintessence, tachyon, K-essence and dilaton are established. We can do this correspondence by comparing the PLECHDE density with the energy density of the scalar field model and also equating their EoS parameters. At last the dynamics of scalar field and its potential for various scalar fields, are obtained.

A. PLECHDE quintessence model

The energy density and pressure density of the quintessence scalar field are given by [30]

$$\rho_\phi = \frac{1}{2}\dot{\phi}^2 + V(\phi), \quad p_\phi = \frac{1}{2}\dot{\phi}^2 - V(\phi). \quad (25)$$

The EoS parameter for scalar field is given by

$$w_\phi = \frac{\dot{\phi}^2 - 2V(\phi)}{\dot{\phi}^2 + 2V(\phi)}. \quad (26)$$

After comparing the EoS parameters of PLECNHDE (16) with scalar field (26), and equating the corresponding energy densities, we find

$$\frac{1}{2}\dot{\phi}^2 + V(\phi) = 3L_{GO}^{-2} - \delta L_{GO}^{-\gamma} \quad (27)$$

$$\frac{\dot{\phi}^2 - 2V(\phi)}{\dot{\phi}^2 + 2V(\phi)} = -\frac{2}{3\beta\Omega_D} \left(\frac{\Omega_D}{1 - \frac{\delta}{3}L_{GO}^{2-\gamma}} + \beta - \alpha \right) - \frac{1}{3}(1 + u). \quad (28)$$

By solving these equations, the dynamics of scalar field and the potential are obtained as

$$\phi^2 = \frac{2}{\beta} \left[\left(\alpha - \beta - \frac{\Omega_D}{1 - \frac{\delta}{3}L_{GO}^{2-\gamma}} \right) + \beta\Omega_D \left(1 - \frac{u}{2} \right) \right], \quad (29)$$

$$V(\phi) = \frac{H^2}{\beta} \left[\left(\frac{\Omega_D}{1 - \frac{\delta}{3}L_{GO}^{2-\gamma}} + \beta - \alpha \right) + \beta\Omega_D \left(\frac{u}{2} + 2 \right) \right]. \quad (30)$$

Integrating Eq. (29) with respect to the scale factor ‘ a ’ yields the evolutionary form of the quintessence scalar field as

$$\phi(a) - \phi(a_0) = \int_{a_0}^a \frac{da}{a\sqrt{\beta}} \left[2 \left(\alpha - \beta - \frac{\Omega_D}{1 - \frac{\delta}{3}L_{GO}^{2-\gamma}} \right) + \beta\Omega_D(2 - u) \right]^{1/2} \quad (31)$$

In the limiting case, same as end of previous section, for $\delta = \Omega_K = u = 0$ and $\Omega_D = 1$, exactly as the same as [17], we obtain

$$\phi = \sqrt{\frac{2\beta}{\alpha-1}} \ln t, \quad (32)$$

$$V(\phi) = \frac{3\beta - \alpha + 1}{(\alpha - 1)^2} \exp\left(-\sqrt{\frac{2(\alpha - 1)}{\beta}}\right). \quad (33)$$

B. PLECHDE tachyon model

One of the well known scalar field that has been considered as the source of dark energy is the tachyon field [31, 32]. It is an unstable field which can be used in string theory through its role in the Dirac-Born-Infeld (DBI) action to describe the D-bran action [33]. The effective Lagrangian for the tachyon field is given by

$$\mathcal{L} = -V(\phi)\sqrt{1 - g^{\mu\nu}\partial_\mu\phi\partial_\nu\phi},$$

where $V(\phi)$ is the potential of tachyon. The energy density and pressure of the tachyon field are given by [33]

$$\rho_\phi = \frac{V(\phi)}{\sqrt{1 - \dot{\phi}^2}}, \quad (34)$$

$$p_\phi = -V(\phi)\sqrt{1 - \dot{\phi}^2}. \quad (35)$$

The EoS parameter of tachyon can be obtained as

$$w_\phi = \frac{p_\phi}{\rho_\phi} = \dot{\phi}^2 - 1. \quad (36)$$

The correspondence between the interacting PLECHDE and the tachyon scalar field model can be established, by comparing Eqs.(4) and (34), and equating Eqs.(16) and (36). By performing these actions, the dynamics of scalar field and potential are given by

$$\dot{\phi}^2 = 1 + w_D = \frac{2}{3\beta\Omega_D} \left(\alpha - \beta - \frac{\Omega_D}{1 - \frac{\delta}{3}L_{GO}^{2-\gamma}} \right) + \frac{1}{3}(2 - u), \quad (37)$$

$$V(\phi) = \rho_D\sqrt{-w_D} = H^2\sqrt{\frac{3\Omega_D}{\beta}}\sqrt{2\left(\frac{\Omega_D}{1 - \frac{\delta}{3}L_{GO}^{2-\gamma}} + \beta - \alpha\right) + \beta\Omega_D(1 + u)}. \quad (38)$$

The evolutionary form of the tachyon scalar field is obtained as

$$\phi(a) - \phi(a_0) = \int_{a_0}^a \frac{da}{aH} \left[\frac{2}{3\beta\Omega_D} \left(\alpha - \beta - \frac{\Omega_D}{1 - \frac{\delta}{3}L_{GO}^{2-\gamma}} \right) + \frac{1}{3}(2 - u) \right]^{1/2}. \quad (39)$$

In the limiting case, for $\delta = \Omega_K = u = 0$, the dynamics of scalar field for a universe which is filled only by new holographic tachyon dark energy ($\Omega_D = 1$), can be obtained

$$\dot{\phi} = \sqrt{\frac{2(\alpha - 1)}{3\beta}}. \quad (40)$$

After integration with respect to time, and using Eqs. (38, 22), one obtains

$$\phi = \sqrt{\frac{2(\alpha - 1)}{3\beta}} t, \quad (41)$$

$$V(\phi) = \frac{2\beta}{(\alpha - 1)\phi^2} \sqrt{\frac{1 + 3\beta - 2\alpha}{3\beta}}, \quad (42)$$

where we assumed the integration constant equal to zero. These relations are in exact agreement with [17].

C. PLECHDE K-essence model

Another famous scalar field which can explain the late time acceleration of the universe is K-essence scalar field. It has been considered by many authors for dark energy modeling. The general scalar field action for K-essence model as a function of ϕ and $\chi = \dot{\phi}^2/2$ is given by [34]

$$S = \int d^4x \sqrt{-g} p(\phi, \chi), \quad (43)$$

where the Lagrangian density $p(\phi, \chi)$ relates to a pressure and energy densities through the following relations:

$$p(\phi, \chi) = f(\phi)(-\chi + \chi^2), \quad (44)$$

$$\rho(\phi, \chi) = f(\phi)(-\chi + 3\chi^2). \quad (45)$$

In this model $\dot{\phi}^2 = 2\chi$. The EoS parameter of K-essence scalar field is given by

$$\omega_K = \frac{p(\phi, \chi)}{\rho(\phi, \chi)} = \frac{\chi - 1}{3\chi - 1}. \quad (46)$$

After equating the EoS parameters of K-essence field and PLECHDE, we can find the expression for dynamics of scalar field $\dot{\phi}^2$ as

$$\dot{\phi}^2 = 2\chi = 2 \frac{w_D - 1}{3w_D - 1} = \frac{2}{3} \left[1 + \frac{2\beta\Omega_D}{2 \left(\frac{\Omega_D}{1 - \frac{\delta}{3} L_{GO}^2} + \beta - \alpha \right) + \beta\Omega_D(u + 2)} \right]. \quad (47)$$

By equating Eqs.(45) with (4), using Eq.(18), we get the expression for $f(\phi)$ as

$$f(\phi) = \frac{9H^2}{2\beta} \frac{[2(L_{GO}^{-2}H^{-2} + \beta - \alpha) + \beta\Omega_D(u+2)]^2}{2(L_{GO}^{-2}H^{-2} + \beta - \alpha) + \beta\Omega_D(u+4)}. \quad (48)$$

The evolutionary form of the K-essence scalar field is obtained as

$$\phi(a) - \phi(a_0) = \sqrt{\frac{2}{3}} \int_{a_0}^a \frac{da}{aH} \left[1 + \frac{2\beta\Omega_D}{2\left(\frac{\Omega_D}{1-\frac{\delta}{3}L_{GO}^{2-\gamma}} + \beta - \alpha\right) + \beta\Omega_D(u+2)} \right]^{1/2}. \quad (49)$$

In the limiting case, for $\delta = \Omega_K = u = 0$ and $\Omega_D = 1$, the dynamics of scalar field and $f(\phi)$ reached to

$$\dot{\phi} = \sqrt{\frac{2}{3} \left(\frac{3\beta - \alpha + 1}{2\beta - \alpha + 1} \right)} \quad (50)$$

$$f(\phi) = \frac{6\beta(2\beta - \alpha + 1)}{(\alpha - 1)^2\phi^2}. \quad (51)$$

which had been obtained by [17]

D. PLECHDE Dilaton model

The Lagrangian density (pressure) in this model is described by

$$p_d = -\chi + ce^{\lambda\phi}\chi^2, \quad (52)$$

where c and λ are positive constant and $\chi = \dot{\phi}^2$. The dilaton scalar field is originated from the low-energy string action [35].

The corresponding energy density is given by

$$\rho_d = -\chi + 3ce^{\lambda\phi}\chi^2, \quad (53)$$

The correspondence between PLECHDE and dilaton scalar field gives us

$$\omega_d = \frac{-1 + ce^{\lambda\phi}\chi}{-1 + 3ce^{\lambda\phi}\chi} = -\frac{2}{3\beta\Omega_D} \left(\frac{\Omega_D}{1 - \frac{\delta}{3}L_{GO}^{2-\gamma}} + \beta - \alpha \right) - \frac{1}{3}(1+u), \quad (54)$$

$$\rho_d = -\chi + 3ce^{\lambda\phi}\chi^2 = 3L_{GO}^{-2} - \delta L_{GO}^{-\gamma} \quad (55)$$

from these equations, the quantity $\chi ce^{\lambda\phi}$ is given by eq.(54)

$$\chi ce^{\lambda\phi} = \frac{w_D - 1}{3w_D - 1} = \frac{1}{3} \left[1 + \frac{2\beta\Omega_D}{2\left(\frac{\Omega_D}{1-\frac{\delta}{3}L_{GO}^{2-\gamma}} + \beta - \alpha\right) + \beta\Omega_D(u+2)} \right]. \quad (56)$$

Using $\chi = \dot{\phi}^2/2$, one can rewrite (56) with respect to ϕ as

$$\frac{d}{dt}e^{\lambda\phi/2} = \frac{\lambda}{\sqrt{6c}} \sqrt{1 + \frac{2\beta\Omega_D}{2\left(\frac{\Omega_D}{1-\frac{\delta}{3}L_{GO}^{2-\gamma}} + \beta - \alpha\right) + \beta\Omega_D(u+2)}},$$

the evolutionary form of the dilaton scalar field is written as

$$\phi(a) = \frac{2}{\lambda} \ln \left\{ e^{\lambda\phi(a_0)/2} + \frac{\lambda}{\sqrt{6c}} \int_{a_0}^a \frac{da}{aH} \sqrt{1 + \frac{2\beta\Omega_D}{2\left(\frac{\Omega_D}{1-\frac{\delta}{3}L_{GO}^{2-\gamma}} + \beta - \alpha\right) + \beta\Omega_D(u+2)}} \right\}. \quad (57)$$

In the limiting case, for $\delta = \Omega_K = u = 0$ and $\Omega_D = 1$, the dilaton scalar field is obtained as

$$\phi(t) = \frac{2}{\lambda} \ln \left(\frac{\lambda}{\sqrt{6c}} \sqrt{\frac{1+3\beta-\alpha}{1+2\beta-\alpha}} t \right), \quad (58)$$

where it has a good compatibility with [17]

IV. CONCLUSION

I have been extended the work of Granda and Oliveros (G-O) [17] to power law entropy corrected HDE model. This model has been arisen from the black hole entropy which may lie in the entanglement of quantum field between inside and outside of the horizon. The evolution of energy density, deceleration and EoS parameter of the new PLECHDE in the context of the non-flat universe was obtained. We show that in contrast with NHDE model, in this model the evolution of our universe near the present time ($z = 0$) is compatible with recent observational data which suggest that $w \sim -1$. In NHDE model, w is far from -1 . A comparison between NHDE, PLECHDE with G-O cutoff and PLECHDE in Ricci scale was done. The phantom divide can be crossed at present time if $L_{GO-0}^{-2}H_0^{-2} \gtrsim 0.65$; $q_0 = -0.54$; $w_0 \sim -1$ in PLECHDE-GO model, $L_{R-0}^{-2}H_0^{-2} \gtrsim 1.53$; $q_0 = -0.53$; $w_0 \sim -1$ in PLECHDE-R model. In dark dominated flat universe without any entropy correction, we have $L_{GO-0}^{-2}H_0^{-2} = 1$; $q_0 = -1.23$; $w = -1.56$. Also the transition between deceleration to acceleration phases of expansion, took place at $L_{GO-acc}^{-2}H_{acc}^{-2} \sim 0.38$ in PLECHDE-GO case, while it happened at $L_{GO-acc}^{-2}H_{acc}^{-2} \sim 1$ in PLECHDE-R model. The correspondence between PLECHDE model and some scalar field of dark energy models has been established. The evolutionary treatment of kinetic energy and potential for quintessence, tachyon, K-essence and dilaton fields, are obtained. I show that the results are in exact agreement with previous work in the limiting case of flat, dark dominated and non corrected holographic dark energy which is obtained by Granda and Oliveros [17].

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- [1] L. Perlmutter et al., *Astrophys. J.* **517**, 565 (1999); C. L. Bennett, et al., *Astrophys. J. Suppl.* **148**, 1 (2003); M. Tegmark et al., *Phys. Rev. D* **69**, 103501 (2004); S. W. Allen, et al., *Mon. Not. Roy. Astron. Soc.* **353**, 457 (2004).
- [2] S. Hannestad and E. Mortsell, *Phys. Rev. D* **66**, 063508 (2002); A. Melchiori et al., *Phys. Rev. D* **68**, 043509 (2003); H. Jassal, J. Bagla, and T. Padmanabhan, *Phys. Rev. D* **72**, 103503 (2005).
- [3] W. Zimdahl, and D. Pavon, *Class. Quant. Grav.* **26**, 5461 (2007).
- [4] Y. Bisabr, *Phys. Rev. D* **82**, 124041 (2010).
- [5] A. Khodam-Mohammadi, M. Malekjani, (arXiv:1101.1632)[gr-qc].
- [6] E. Elizalde, S. Nojiri, S.D. Odintsov, and P. Wang, *Phys. Rev. D* **71**, 103504 (2005); M. R. Setare, *Phys. Lett. B* **648**, 329 (2007); M. R. Setare, and M. Jamil, *JCAP*, **02**, 010 (2010); K. Karami, and J. Fehri, *Phys. Lett. B*, **686**, 216 (2010); A. Sheykhi, *Phys. Lett. B* **681**, 205 (2009); M. R. Setare, and S. Shafei, *JCAP* **09**, 011 (2006); M. R. Setare, *Phys. Lett. B* **644**, 99 (2007); M. R. Setare, and E. C. Vagenas, *Phys. Lett. B* **666**, 111 (2008); M. R. Setare, *Phys. Lett. B* **642**, 421 (2006); M. R. Setare, *Phys. Lett. B* **654**, 1 (2007); M. R. Setare, *Eur. Phys. J. C* **52**, 689 (2007); M. Malekjani, and A. Khodam-Mohammadi, *Int. j. Mod. Phys. D*, (2010).
- [7] G. 't Hooft, [gr-qc/9310026]; L. Susskind, *J. Math. Phys.* **36**, 6377 (1995).
- [8] J. D. Bekenstein, *Phys. Rev. D* **7** (1973) 2333; S. W. Hawking, *Comm. Math. Phys.* **43**, 199 (1975); S. W. Hawking, *Phys. Rev. D* **13**, 191 (1976); J. D. Bekenstein, *Phys. Rev. D* **23**, 287 (1981).
- [9] A. Cohen, D. Kaplan, and A. Nelson, *Phys. Rev. Lett.* **82**, 4971 (1999).
- [10] M. Li, X. D. Li, S. Wang, Y. Wang, and X. Zhang, *JCAP* **0912**, 14 (2009); M. Li, X. D. Li, S. Wang, Y. Wang, and X. Zhang, *J. Cosmol. Astropart. Phys.* **06**, 036 (2009).
- [11] M. Li, *Phys. Lett. B* **603**, 1 (2004).

- [12] S. D. H. Hsu, Phys. Lett. B **669**, 275 (2008).
- [13] D. Pavon, and W. Zimdahl, Phys. Lett. B **628**, 206 (2005).
- [14] A. Sheykhi, Class.Quant.Grav.**27**, 025007 (2010).
- [15] S. Nojiri and S. D. Odintsov, Gen. Rel. Grav. **38**, 1285 (2006).
- [16] I. Duran, and D. Pavon, Phys. Rev. D **83**, 023504 (2011).
- [17] L.N. Granda and A. Oliveros, Phys. Lett. B **671**, 199 (2009), arXiv:0810.3663 [gr-qc].
- [18] Granda, L. N., Oliveros, A., Phys. Lett. B **669**, 275 (2008).
- [19] M. Malekjani, A. Khodam-Mohammadi, and N. Nazari-pooya, Astrophys. and space Sci. **332**, 515 (2011).
- [20] R. M. Wald, Phys. Rev. D **48**, 3427 (1993).
- [21] N. Radicella, and D. Pavón, accepted for publication on PLB (2011), (arXiv:1006.3745)[gr-qc].
- [22] M. Jamil, A. sheykhi, M. Farooq, Int. J. Mod. Phys. D **19**, 1831 (2010); M. Jamil, A. sheykhi, Int. J. Theor. Phts. **50**, 625 (2011); K. Karami et al., Gen. Relativ. Grav. **43**, 27 (2011); K. Karami et al., Europhys. Lett. **93**, 69001 (2011) [arXiv:1007.3985]; K. Karami, A. Sheykhi, N. Sahraei, S. Ghaffari, Europhys. Lett. **93**, 29002 (2011); A. Khodam-Mohammadi, M. Malekjani, communications in theoretical physics, **55**, 5, 924 (2011), (arXiv:1004.1720)[gr-qc]; K. Karami, A. Sorouri, Phys. Scripta **82**, 025901 (2010).
- [23] S. Das, S. Shankaranarayanan and S. Sur, Phys. Rev. D **77**, 064013 (2008).
- [24] N. Radicella, and D. Pavon, Phys. Lett. B **691**, 121 (2010).
- [25] S. Das, S. Shankaranarayanan and S. Sur, [arXiv:0806.0402v1]; S. Das, S. Shankaranarayanan and S. Sur, [arXiv:1002.1129v1].
- [26] A. Sheykhi and M. Jamil, accepted for publication in Gen. Relativ. Grav., (arXiv:1011.0134)[hep-th].
- [27] K. Karami and M.S. Khaledian, JHEP **03**,086 (2011).
- [28] Y. Wang, and L. Xu, Phys. Rev. D **81**, 083523 (2010).
- [29] P. Serra et al., Phys. Rev. D **80**, 121302 (2009).
- [30] E.J. Copeland, M. sami, and S. Tsujikawa, Int. J. Mod. Phys. D **15**, 1753 (2006).
- [31] T. Padmanabhan, Phys. Rev. D **66**, 021301 (2002).
- [32] L. R. W. Abramo and F. Finelli, Phys. Lett. B **575**, 165 (2003).
- [33] A. Sen, JHEP **0204**, 048 (2002); A. Sen, JHEP **0207**, 065 (2002); A. Sen, Mod. Phys. Lett. A **17**, 1797 (2002); A. Sen, [hep- th/0312153]; A. Sen, JHEP **9910**, 008 (1999); E. A. Bergshoeff,

- M. de Roo, T. C. de Wit, E. Eyras, and S. Panda, JHEP **0005**, 009 (2000); J. Kluson, Phys. Rev. D **62**, 126003 (2000); D. Kutasov and V. Niarchos, Nucl. Phys. B **666**, 56, (2003).
- [34] C. Armendariz-Picon, T. Damour, and V. Mukhanov, Phys. Lett. B **458**, 209 (1999)
- [35] F. Piazza and S. Tsujikawa, JCAP **0407**,004 (2004).